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RESEARCH PAPER

Alpha and Beta Species Diversity of Freshwater Ostracoda (Crustacea) and Their Seasonal Distribution in Seben-Taşliyayla Reservoir (Bolu, Turkey)

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Abstract

To complete the first long-term study on freshwater ostracods and estimate their alpha and beta species diversity in a newly established Seben-Taşlıyayla Reservoir (Bolu, Turkey) along with nine different environmental variables, monthly samples were collected from 15 stations located around the reservoir between August 2013 and September 2014. A total of 19 taxa (10 living and 9 subfossils) was reported for the first time from the reservoir. *Cypridopsis vidua* was the most frequently occurring species with a wide ecological ranges and seasonal distribution. Numbers of living ostracods (the alpha diversity) were found lower than the average numbers of species per lake in Turkey (13.2 spp./lake). When the alpha diversity of the reservoir (2.079) was in the medium, beta diversity (5.2) was ranged from low to medium. Results exhibited natural aquatic habitats showed relatively higher dissimilarities in species composition than small man-made habitats and the reservoir. A possible implication of finding such low numbers of species in such artificial habitats may depend on the age of the reservoir. Finding most of the cosmopolitan (and cosmoecious) species from the reservoir is the indication of ostracods primary succession. Accordingly, long-term studies are recommended to understand possible changes in species assemblages in future.

Keywords: Alpha and beta diversity, Ostracoda watch model, cosmoecious species, ecological succession.

Introduction

Ostracods, which are microscopic invertebrates, can be found in almost all kinds of aquatic habitats including natural (e.g., oceans, lakes, desert oasis, springs, ponds, creeks, caves) and artificial habitats (e.g., irrigation canals, troughs, dams) (Bronstein, 1947, Danielopol, 1978, Külköylüoğlu, 1998, 2003, Meisch, 2000, Martín-Rubio, Rodriguez-Lazaro, Anadón, Robles, Utrilla, & Vázquez, 2005). Individual species shows different levels of tolerance and optimum values for different environmental variables. Many ostracod species show high tolerance ranges which provide possibilities for species distribution into wide geographical areas. In contrast, some species known with limited tolerance and optimum ranges can be used as bioindicator species to determine water quality, conditions and temporal changes in those of particular habitats (Benson, 1990, Külköylüoğlu, Yavuzatmaca, Akdemir, & Sarı, 2013, Wezel et al., 2014). However, using ostracods as bioindicator species requires a deep understanding of their ecological preferences. Since ostracods' carapace structure consists of high amount of $CaCO_3$, they can be fossilized in the sediments (Tuncer & Tunoğlu, 2014, Tunoğlu, Tuncer, Karakaya-Çelik, & Karakaya, 2014). Therefore, finding the fossil and/or living ostracod forms can provide the opportunity to predict past environmental conditions from the recent living species. In such a way, reconstruction of past history can be made for that of particular area. Hill (1973) pinpointed theoretical utility of species diversity resulting from its relationship to evolutionary time, stability, productivity, predation pressure, maturity, and spatial heterogeneity. Magurran (1988) underlines the importance of species diversity for at least three reasons; i) maintaining well-documented patterns of spatial and temporal variations on the topic (diversity) as an important subject in ecology; 2) providing knowledge about ecology of an area (or the quality of aquatic habitats) by means of using indicator species; and 3) raising discussion about the measurement of diversity. Besides, there can be two more reasons for the importance of diversity. First is the increasing interest in conservation of natural habitats, and second is the diversity of species which can provide an insight into the knowledge of evolutionary succession of species in the variety of habitats. There are several methods of measuring species diversity (see e.g., McIntosh, 1967, Hurlbert, 1971, Whittaker, Gilbert, & Connell, 1979, Lande, 1996, Novotny & Missa, 2000, Veech

Summerville, Crist, & Gering, 2002). Types of diversity can be studies at three different levels: alpha (α, local richness), gamma (γ, regional richness) and beta diversity (β, differences in diversity of habitats, local or regional areas) (Wilson & Shmida, 1984, Magurran, 1988, Ås, 1999, Clarke & Lidgard, 2000). Accordingly, habitats or communities sharing with fewer species display high beta diversity (Whittaker, 1960, 1972). Wilson and Shmida (1984) indicated that beta diversity based on quantitative data can be important for several reasons. First, it exhibits the degree of habitats used and/or shared by species. Second, it is possible to compare and contrast different habitat diversity. Hence, measuring beta diversity (along with alpha richness) can provide knowledge on the total diversity.

In terms of ostracods, diversity measurements have been used to understand spatial distribution of the species among the variety of aquatic habitats (Akdemir, 2008, Akdemir & Külköylüoğlu, 2014, Yavuzatmaca, Külköylüoğlu, & Yılmaz, 2015). Although applications of beta (Koleff, Gaston, & Lennon, 2003) and alpha measurement are recognized in different scientific studies, there are few studies on local diversity of ostracods (Nagorskaya & Keyser, 2005, Higuti, Lansac-Tôha, Velho, & Martens, 2009, Külköylüoğlu, Yavuzatmaca, Akdemir, & Sarı, 2012) and on global or continental perspective (Martens 1998, Martens & Ortal, 1999). Unfortunately, these studies are not long-term studies and do not examine ostracods alpha and beta diversities in a man-made reservoir. Külköylüoğlu (2009) stated that newly established (artificial) habitats do not show true diversity values because there has not been enough time for building up suitable conditions for species (i.e., ostracods) succession. In general term, succession covering changes in natural habitats along with species composition (Connell & Slatyer, 1977) can be classified into two main stages: i) primary succession; a disturbance opens relatively large areas or releases the resources for those species to colonize the area after that first comers. After that the area can be available for other species, and ii) secondary succession; it can occur after critical changes (or maybe called "disturbance") are observed on the habitats by means of natural or artificial activities. The idea of succession in nonmarine ostracods was first used in a small spring in Bolu (Turkey) by Külköylüoğlu (2009) who showed the effect of seasonality on species succession. This is the first study on the reservoir since its establishment. Therefore, it is important to test the ideas mentioned above. Hence, we believe that the present study can be used as a guiding work for future studies. The aim of this study were (1) to estimate alpha and beta species diversities of ostracods in Seben-Taşlıyayla reservoir, (2) to understand their seasonal distribution, and (3) to determine beta diversity values for type of natural and artificial aquatic bodies.

Materials and Methods

Site Description

Taşlıyayla-Seben reservoir (40°30'57"N, 31°38'32"E) is located about 22 km South of Bolu province at 1450 m of elevation. The reservoir covers about 8.33 km2 of surface area with the volume of 44 x 106 m3 (Figure 1), where maximum depth is about 12m (BİÖİ, 2003). The maximum length is nearly 5 km while the width 2.6 km long. There are seven plateaus (Ayman, Solaklar, Nimetli, Alpagut, Dedeler, Demirciler, Çavuşlar) around the reservoir. The building of the reservoir began in 2005 and finished in 2008. Water level of the reservoir reached to its estimated level after the year 2009. The lake is mainly fed by Aladağ stream, few springs, snow melt and rain water. Since its establishments, this is the

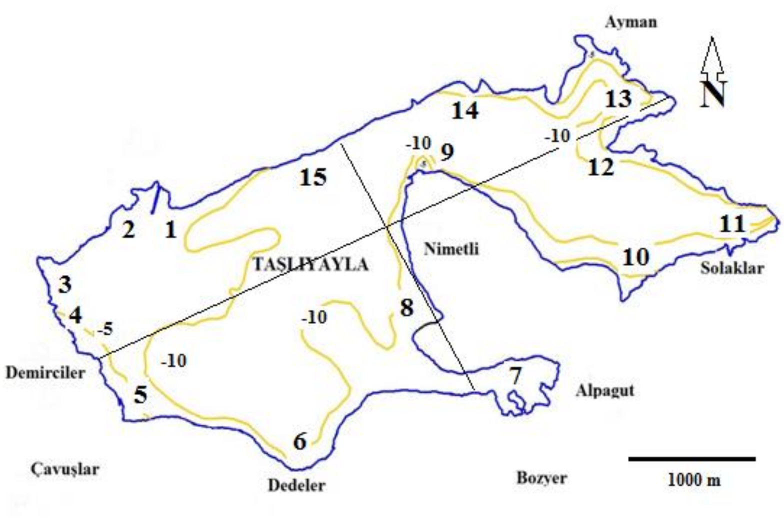

Figure 1. Sampling stations (big bold numbers from 1-15) and depth counterlines (-5, -10) ranges around littoral zone of Seben-Taşlıyayla reservoir (Bolu, Turkey). Solid black lines represent maximum length and width. Modified and redrawn from General Command of Mapping 25000:1 templates.

first long-term study on the reservoir species diversity and its physicochemical and ecological features.

Sampling

We collected water samples from 15 stations around the reservoir between August 2013 and September 2014. Sampling was not possible in January 2014 due to ice cover. All materials were collected with a standard hand net (200 mm mesh size) and fixed in 70% of ethanol in situ after environmental variables were measured. In the laboratory, samples were filtered in four standardized sieves (0.25; 0. 50; 1:00; 1.5 mm mesh size) and ostracods were separated from the sediments under the stereomicroscope. Species identification was done following the systematic keys of Meisch (2000). Valves and carapaces were photographed under JEOL JSM-639LV model scanning electron microscope (JEOl SEM version 8.25).

Statistical Analyses

Ostracoda Watch Model (Külköylüoğlu, 1998) was used to show species seasonal distribution while a non-parametric Spearman Correlation analysis was run to show possible correlations among the species and variables. Regression analyses were used to estimate the effect of association between air and water temperatures. Alpha and beta diversity values were compared with those of known species diversity in 16 different lakes and reservoir. Alpha (Shannon-Wiener) and beta (Whittaker Beta) diversity values were calculated with a Species Diversity and Richness (SDR) 4.1.2. program.

Measures of beta diversity was based on the presence and absence data. Unweighted pair group method with arithmetic mean (UPGMA) used with Jaccard's coefficient was selected to identify different clustering assemblages of the species. UPGMA was performed with a multivariate statistical package program (MVSP, version 3.1) (Kovach, 1998). A multiprobe (YSI-Professional Plus) field tool was used to measure dissolved oxygen concentration, water temperature, electrical conductivity, salinity, pH, and total dissolved solids. Elevation and coordinates were reported with a Geographic Positioning System (GPS) (GARMIN Etrex Vista H). A Kestrel-3000 model of anemometer was used to obtain air temperature, relative humidity, and wind speed of each site.

Results

During the present study, we collected 19 ostracod taxa including 10 living (Candona weltneri, Candona sp., Cypridopsis vidua, Herpetocypris chevreuxi, Heterocypris salina, H. incongruens, Limnocythere inopinata, Potamocypris variegata, Potamocypris sp., Koencypris ornata) and nine subfossils (Cypridopsis sp., Herpetocypris sp., Heterocypris sp., Ilyocypris sp., Isocypris sp., Limnocythere sp., Prionocypris zenkeri, Cavernocypris sp., Zonocypris sp.) (Appendix, B). All of the species listed here are new reports for the reservoir. According to OWM (Figure 2), seasonality of the species showed variations; for instance, four

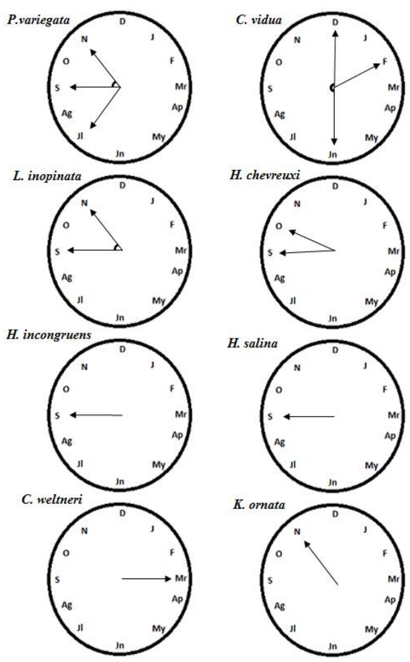

Figure 2. Ostracod Watch Model shows seasonal and monthly (D, December; J, January; F, February; etc.) occurrences of 8 species. Single arrow represents one-time occurrence of the species. Angle between two arrows displays occurrence of the species between the corresponding months. Modified from Külköylüoğlu (1998).

species (H. incongruens, H. salina, C. weltneri and K. ornata) occurred once in a year while H. chevreuxi was seen twice in fall seasons (October 2013 and September 2014). When C. vidua was the most frequently occurring species with wide ecological ranges to pH (7.53 – 9.47), DO (4.57 – 14.77 mg/L) and water temperature (6 – 27.3 °C), L. inopinata was encountered in a wide range of redox potential (1 – 283 mV). Effective contribution of C. vidua was eventually highest among the other species (15.20%) (Table 1). During the sampling period of three months (February, April and May), no living adult species was found from the reservoir (see discussion below) (Figure 3).

Spearman correlation analyses displayed a positive strong relationship between water and air temperature ($P<0.01$) when both temperature values were increased during the study periods. A strong negative correlation was found between DO ($P<0.01$) and EC, water and air temperature while the

Table 1. Mean, minimum and maximum values nine different environmental variables from 15 stations in Taşlıyayla-Seben reservoir. Abbreviations: Moi (%), Percent moisture), Wind (wind speed), Ta (air temperature), DO (dissolved oxygen), EC (electrical conductivity), Sal (salinity), Tw (water temperature), TDS (total dissolved solids), Code (species code), Cv (*Cypridopsis vidua*), Hi (*Heterocypris incongruens*), Hs (*H. salina*), Hc (*Herpetocypris chevreuxi*), Ko (*Koencypris ornata*), Pv (*Potamocypris variegata*), Li (*Limnocythere inopinata*), Cw (*Candona weltneri*)

Station No		Moi (%)	Wind	Ta	pH	DO	EC	Sal	Tw	TDS	Code
1	Mean	47.15	9.40	16.51	8.35	14.81	97.95	0.10	13.81	0.081	Cv, Hc
	min	34.10	1.90	4.80	7.98	4.64	54.50	0.05	2.80	0.056	
	max	75.10	19.70	28.50	9.08	65.60	175.20	0.06	25.90	0.135	
2	Mean	44.29	5.13	17.91	8.10	10.31	90.18	0.05	15.08	0.069	Cv
	min	25.20	0	4.90	7.44	6.39	69.80	0.05	4.20	0.023	
	max	90.50	12.14	28.00	8.93	14.80	112.50	0.06	24.90	0.077	
3	Mean	43.20	5.74	18.21	7.74	9.41	86.40	0.05	14.26	0.070	Cv, Hs, Ko
	min	20.40	0	4.70	4.46	2.90	37.90	0.03	1.80	0.045	
	max	94.50	15.80	27.10	8.47	19.20	111.50	0.06	23.10	0.077	
4	Mean	42.56	6.32	18.29	8.12	10.96	86.98	0.05	14.86	0.070	Cv,Pv
	min	16.20	2.10	3.20	7.45	5.30	56.60	0.04	3.50	0.061	
	max	92.40	13.70	29.20	8.73	16.73	109.40	0.05	24.00	0.075	
5	Mean	44.77	12.84	17.91	8.11	10.29	93.32	0.05	15.11	0.075	Cv, Li, Pv
	min	17.30	1.90	6.10	7.50	3.99	73.20	0.05	4.20	0.066	
	max	78.50	46.20	26.10	8.77	20.49	122.10	0.06	25.60	0.082	
6	Mean	45.62	9.45	18.15	8.18	11.27	87.15	0.05	15.83	0.068	Cv, Li, Pv
	min	22.10	1.80	4.30	7.65	5.21	41.20	0.03	4.40	0.043	
	max	92.20	21.70	26.30	9.13	18.03	112.40	0.06	26.90	0.077	
7	Mean	44.93	11.45	17.38	8.51	11.77	92.27	0.05	17.58	0.067	Cv,Cw
	min	22.30	3.00	3.90	7.65	4.79	54.40	0.04	3.00	0.053	
	max	68.60	23.90	27.60	9.47	20.40	114.30	0.05	28.10	0.073	
8	Mean	39.89	7.43	19.37	8.29	10.69	92.83	0.05	16.79	0.072	Cv,Pv
	min	18.30	1.50	9.90	7.74	5.32	71.80	0.05	5.20	0.067	
	max	62.70	18.30	27.10	9.43	15.37	113.10	0.05	27.30	0.075	
9	Mean	44.04	7.86	18.138	8.17	10.56	87.938	0.05	14.43	0.072	Cv
	min	14.50	2.40	3.7	7.58	5.87	70.5	0.05	4.60	0.065	
	max	79.10	23.50	31.3	8.64	17.63	108.8	0.06	23.60	0.076	
10	Mean	42.65	9.91	18.454	8.33	11.03	89.300	0.05	16.25	0.069	Cv
	min	17.90	1.80	7.4	7.64	5.82	56.3	0.04	5.20	0.053	
	max	65.40	20.20	25.5	9.47	17.50	115.1	0.05	26.60	0.076	
11	Mean	39.97	8.53	18.031	8.05	9.75	87.754	0.05	14.41	0.072	Cv
	min	15.30	2.00	4.2	7.58	4.04	67.8	0.05	4.10	0.065	
	max	62.30	22.30	26.2	8.54	14.81	108.1	0.05	23.60	0.076	
12	Mean	40.25	5.29	19.108	8.18	10.76	87.754	0.05	16.80	0.069	Cv,Hi
	min	20.20	1.70	6.2	7.62	5.66	59.6	0.04	3.90	0.061	
	max	65.20	15.20	29.4	9.11	16.70	110.9	0.05	26.80	0.075	
13	Mean	39.39	4.81	19.962	8.14	10.34	90.208	0.05	15.50	0.072	Cv,Hc, Ko
	min	22.20	1.50	5.6	7.58	5.25	72.5	0.05	5.50	0.065	
	max	74.20	11.90	32.7	8.97	15.88	121.2	0.06	24.40	0.080	
14	Mean	40.84	7.85	18.469	8.04	9.36	87.585	0.05	15.36	0.070	
	min	24.50	2.10	6.1	7.51	3.48	40.8	0.03	3.40	0.045	
	max	66.70	25.20	28.4	8.67	9.19	109	0.06	23.50	0.077	
15	Mean	41.80	7.20	18.138	7.98	9.19	97.277	0.05	15.31	0.078	Cv
	min	21.90	2.10	5.2	7.44	4.01	40.8	0.02	5.30	0.042	
	max	73.80	21.20	28.7	8.44	74.2	127.4	0.08	27.00	0.116	

correlation was positive between pH (P<0.05) and EC, water and air temperature. As expected, EC showed the strong positive relationship with water and air temperature. According to UPGMA analyses (Figure 4), Taşlıyayla-Seben reservoir was closely clustered to Gölcük Lake which is a man-made lakelet. Among the all Shannon alpha sample index value for 16 different aquatic bodies, alpha diversity of the reservoir (2.079) was in the medium (Table 2). Besides, Whittaker beta diversity index value (5.2) showed that the reservoir ostracod species composition was low-medium among the aquatic bodies in similar type and size.

Discussion

Similar to earlier findings (Kothandaramans & Evans, 1972, Morril, Bales, & Conklin, 2005, O'Reilly *et al*., 2015), our results support a linear relationship between air and water temperatures. The effect of air temperature on the water can be stronger along the littoral zone than pelagic and deep benthic zones. This seems the case in the present study where sampling stations were arranged around the littoral zone of the reservoir. The implication of this relationship is to recognize the fact that temperature changes can be one of the most effective factors on species composition since most of the ostracods inhabiting littoral zones (or shallow water bodies) where they show species-specific seasonal occurrences. However, we did not find a significant relationship between the species and seven of those environmental variables. There can be a couple of reasons for this result such as, short sampling time, the age of the reservoir, and/or ecological succession of individual species. It is clearly stated that newly developed environments or habitats generally have low species composition. Connell and Slatyer (1977) the environment or habitats in their first developmental stages can be first hosted by only a few species. This is because of the unavailabilities of the environment for most other species. According to Külköylüoğlu (2009) these kinds of environments can be first colonized by cosmopolitan species that have usually wide ecological distribution and tolerance ranges (Külköylüoğlu, 2009). Increasing numbers of cosmopolitan over non-cosmopolitan species can be interpreted as the ratio of "pseudorichness" (Külköylüoğlu Dügel, & Kılıç, 2007). Application of this concept revealed high levels of a pseudorichness

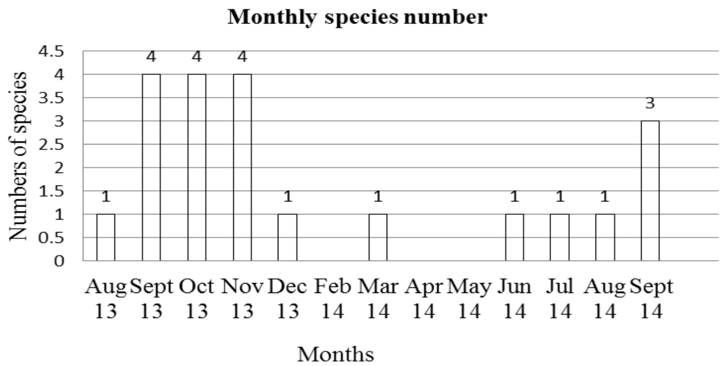

Figure 3. Numbers of species per month in the study area. Note that species were not found in February, April and May of 2014. Numbers above the bars show numbers of species.

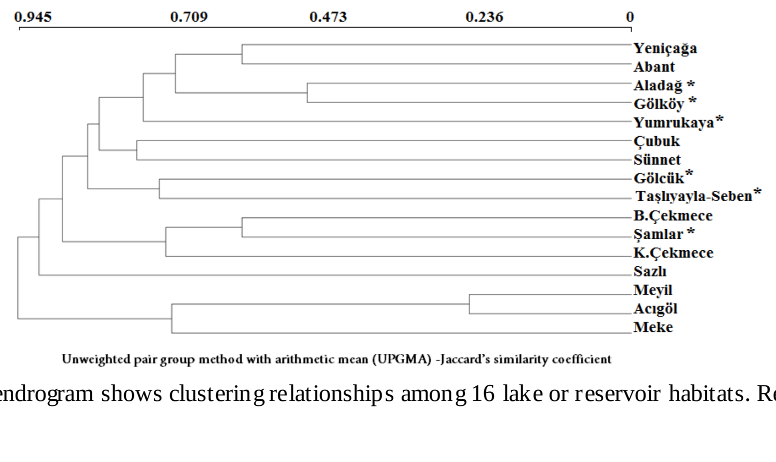

Figure 4. UPGMA dendrogram shows clustering relationships among 16 lake or reservoir habitats. Reservoirs are shown with asterisk (*).

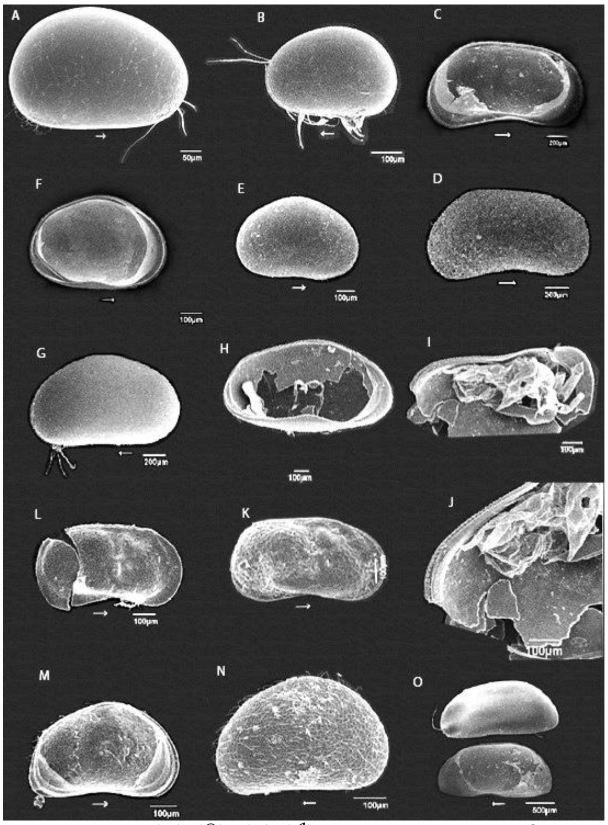

Figure 5. SEM Photos *Cyclocypris globosa* (A) (♀), (B) (♂), *Candona weltneri* left valve internal (C), *C. weltneri* right valve external (D), *Cypridopsis vidua* right valve external (E), *C. vidua* left valve internal (F), *Heterocypris incongruens* left side individual (G), *H. salina* left valve internal (broken while preparation) (H), *H. salina* right valve internal (broken while preparation) (I, J), *Limnocythere inopinata* right valve external (K), *L. inopinata* left valve internal (L), *Potamocypris variegata* left valve internal (M), *P. variegata* right valve external (N), *Stenocypria fischeri* left valve external (upper) and right valve internal (lower) (O).

Table 2. Average abundance (AvAb), similarities (AvSi) and percent contribution (%Con) of 13 species reported during this study. Note to the species outside of the reservoir

Name	AvAb	AvSi	% Con
Cypridopsis vidua	0.625	3.43389	15.2043
Ilyocypris bradyi	0.5625	2.9024	12.851
Eucypris virens	0.5	2.27952	10.0931
Limnocythere inopinata	0.4375	1.71944	7.61321
Candona neglecta	0.4375	1.68916	7.47913
Physocypria kraepelini	0.4375	1.44076	6.37931
Darwinula stevensoni	0.375	1.30779	5.79054
Heterocypris incongruens	0.375	1.04582	4.63059
Heterocypris salina	0.25	0.883929	3.91379
Candona candida	0.3125	0.763451	3.38035
Ilyocypris gibba	0.3125	0.676195	2.99401
Cypria ophtalmica	0.3125	0.659951	2.92208
Herpetocypris chevreuxi	0.25	0.527103	2.33387

ratio (noncosmopolitan/cosmopolitan 0.33) in Taşlıyayla reservoir. In contrast, Lake Aladağ, a small man-made reservoir (Yılmaz & Külköylüoğlu, 2006), with seven species showed smaller ratio of pseudorichness (0.17). Similar results were also reported from a couple of other reservoirs located in the same region. For example, while Gölköy reservoir had 0.22 of pseudorichness atios with 11 species, the ratio was 0.2 in another reservoir Gölcük reservoir with six species (Külköylüoğlu, 2005a, Külköylüoğlu & Dügel, 2004, respectively). Conversely, the natural lakes (e.g., Lake Sünnet (Külköylüoğlu *et al*., 2010 and Lake Çubuk (Külköylüoğlu *et al*., 2014) had the higher pseudorichness ratio (0.80 and 0.89 pseudorichness ratios, respectively) than those of man-made habitats (Külköylüoğlu, 2013). There is a

Table 3. Alpha diversities of Shannon (H) index along with variance (Var. H) and expected (Exp. H) values for 16 aquatic bodies

Sample	H	Var. H	Exp. H
Yeniçağa	2.565	0.0355	13
Yumrukaya	1.792	0.06944	6
Gölcük	1.792	0.06944	6
Aladağ	1.946	0.06122	7
Abant	2.708	0.03111	15
Gölköy	2.398	0.04132	11
Sazlı	1.609	0.08	5
Çubuk	2.833	0.02768	17
Taşlıyayla-Seben	2.079	0.05469	8
Sünnet	2.197	0.04938	9
B.Çekmece	2.944	0.02493	19
K.Çekmece	2.485	0.03819	12
Şamlar	2.773	0.0293	16
Meyil	2.079	0.05469	8
Meke	0.6931	0.125	2
Acıgöl	1.792	0.06944	6
All Sample Index	3.812		
Jackknife Std Error	0.1166		

nexus between the ratio of pseudorichness and alpha diversity; if ratio increases, evenness of alpha decreases, implying dominancy of cosmopolitans on the species community. This is probably the case in Taşlıyayla-Seben reservoir when we compare the average numbers of species per station (1.73 spp./station). This is 4.7, 4.6 and 4.14 in Lake Abant, Lake Gölköy and Lake Aladağ, respectively. Hence, comparing to these aquatic bodies, the reservoir has the largest surface area. However, finding low alpha diversity may indicate the fact that the reservoir is in its early succession stages for ostracods (if not others). Our results suggested that degree of dis/similarities may depend on sampling intensity or sample size. Clarke and Lidgard (2000) emphasized that a relatively small number of samples per bin (latitudinal or provincial) particularly affected regional (γ) species richness, but a linear relationship was also observed between the number of samples and regional species richness. Similarly, in the present study, one may reconsider the relationship among alpha, beta and gamma diversities in Whittaker's model. When there is no change in local diversity, any increase in the gamma diversity due to increase in the number of samples (by means of elevating the chance of getting more species per sample) will increase beta diversity. Accordingly, increasing numbers of cosmopolitan (e.g., invader) species in natural areas has been known to reduce the numbers of native species and total biodiversity, affecting the ecosystem function (e.g., see Hokkanen & Pimentel, 1984, Kirkpatrick & Barton, 1997, Külköylüoğlu, 2008). Overall, declining trend in global biodiversity because of dormancy in invasive species is called 'mongrelization' (Meffe & Carroll, 1994). This can also be known as a signal of reduction in habitat quality. Such declines in quality can eventually change diversity measurements at alpha, beta and gamma diversity levels. Working on bryozoan species richness in the North Atlantic, Clarke and Lidgard (2000) related differences in species turnover (beta diversity) on large spatial scales to both the degree and scale of spatial heterogeneity in that certain area. At a more local scale, this implies that the lakes with cosmopolitan ostracods should be more similar than lakes without sharing cosmopolitan species. This is therefore another possible and tentative explanation of finding low numbers of species in the reservoir. On the other hand, focusing on the performance of 15 beta diversity measurements, Cardoso, Borges, and Veech (2009) underlined the fact that there are no index without bias in all circumstances. The authors pinpointed the importance of sampling efforts. Accordingly, they showed the values of all measures change with varying sampling completeness. This reveals more sampling in variety of habitats. Indeed, we had also two additional sampling sites nearby the study area where we found 6 living taxa (*Candona neglecta*, *Cyclocypris globosa*, *Cyclocypris* sp., *Cypria* sp., *Cypridopsis vidua*, *Potamocypris variegata*) reported from a pool located 6 km north from the reservoir and three living species (*C. globosa*, *Stenocypria fischeri*, *C. vidua*) from a pond located 150m east from the reservoir. Most of the species are not known from the reservoir. Thus, implication of the earlier studies (e.g., see Cardoso, Borges, & Veech, 2009) to the present one may be that our sampling period was not long enough to see complete faunal diversity. On the other hand, our results support the earlier view that newly established habitats (e.g., reservoirs) favor species with cosmopolitan (or cosmoecious) characteristics due to high tolerance levels of these species to different environmental factors. Also, since our sampling was limited with littoral zones, we suggest that future studies would consider samplings from limnetic and deeper parts of the reservoir. This can contribute more on our understanding about species composition. Therefore, we suggest additional long-term biomonitoring studies on the reservoir to observe future diversity changes.

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